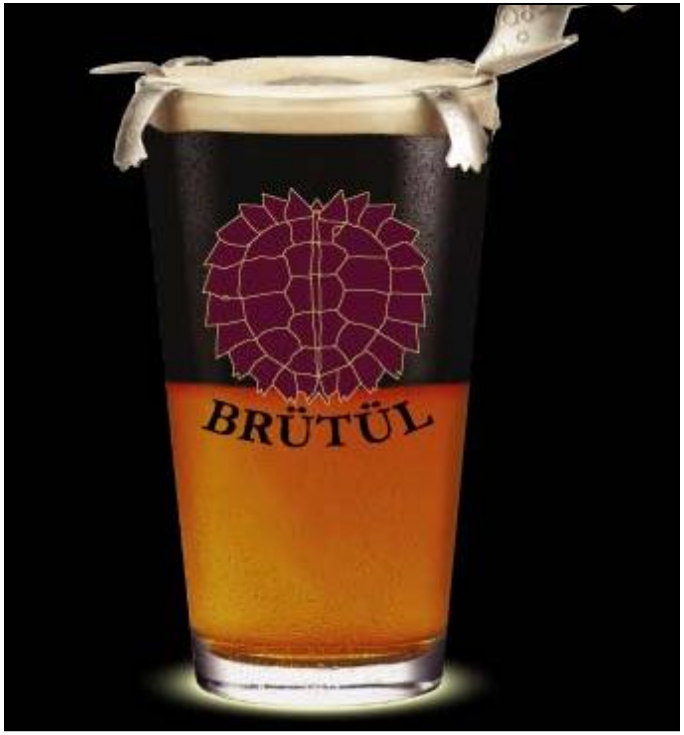
Mixing Zones 101

Chelsea Morris
Standards and Health Protection Division
Office of Science and Technology

Complete Mixing: Chicago River & the White House

No Mix: Perfect Black and Tan



Mixing Demonstration: The Breakfast Experiment

What is a Mixing Zone?

- A mixing zone is:
  - A limited area or volume of water where initial dilution of a discharge takes place and where numeric water quality criteria can be exceeded (WQS Handbook, 1994)

- Rationale: Sometimes organisms can be exposed to a magnitude above a criterion for a short duration without interfering with the designated use of a waterbody as a whole

What is a Mixing Zone?

- Two meanings:
  - *Regulatory mixing zone:* contained in the general policies section of a state's or tribe's WQS, at the state's or tribe's discretion
  - *Physical mixing zone*: calculated and implemented on a site-specific basis through a facility's NPDES permit

- A mixing zone is <u>not</u>:
  - A water quality criterion or a change to a water quality criterion
  - An area where water quality criteria do not apply

Mixing Zone Examples

Atmospheric example of turbulent buoyant jet mixing in a stratified shear flow.
Source: Ralph Turcotte, Beverly (Massachusetts) Times from www.cormix.info

Firebreather
Source: www.cormix.info

Mixing Zone Examples

Far-field plume mixing in River
Source: www.cormix.info

Wastewater outfall with boundary interaction
Source: I. Wood from www.cormix.info

Mixing Zone Authority

- 40 CFR 131.13: General Policies: States may, at their discretion, include in their State standards policies generally affecting their application and implementation, such as mixing zones, low flows and variances. Such policies are subject to EPA review and approval.

Mixing Zone Authority

- 40 CFR 122.44(d)(1)(ii): In determining whether a discharge causes, has the reasonable potential to cause, or contributes to an in-stream excursion above a narrative or numeric water quality standard, the permitting authority shall use procedures which account for…where appropriate, the dilution of the effluent in the receiving water.

Mixing Zone "Shoulds"

- Be no larger than necessary
- Protect the designated use of the waterbody as a whole
- Prevent lethality to passing organisms
- Prevent significant health risks

Mixing Zone "Should NOTs"

- Be used as a way to lower a designated use
- Be used as a way of revising criteria or developing site-specific criteria outside of the water quality standards process
- Overlap

Purpose of a Mixing Zone Policy

- Restrict areas where numeric criteria may be exceeded to known and controlled locations
- Reduce need for excessive wastewater treatment

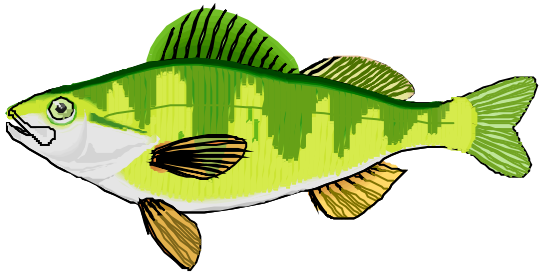
Contents of a Mixing Zone Policy

- Statement specifying when and where mixing zones are allowed (if at all)

- Necessary information for defining mixing zone characteristics including:
  - Location
  - Size / shape (including flow)
  - Outfall design
  - In-zone water quality

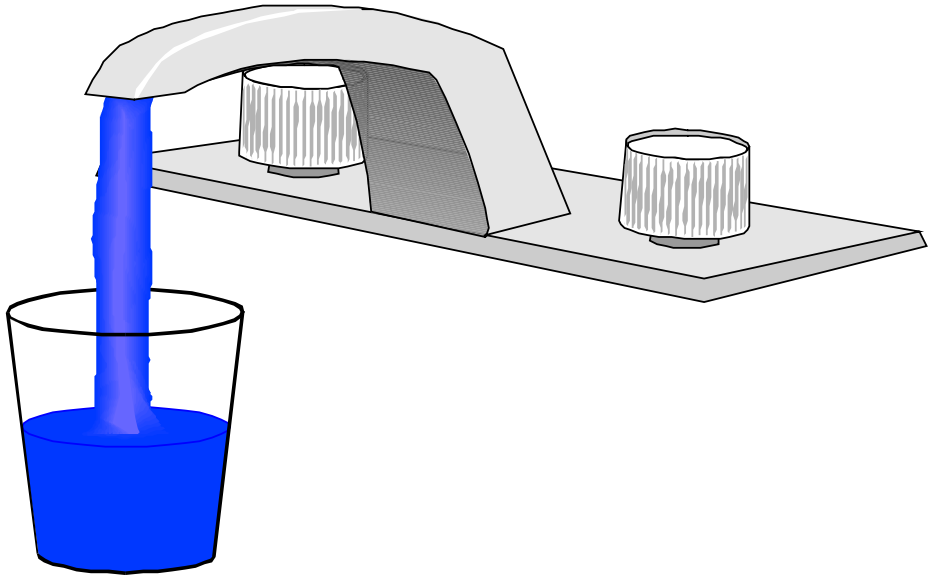
Mixing Zone Location: Aquatic Life

- Identify and protect biologically important and sensitive areas
  - Shellfish beds
  - Breeding and spawning areas
  - Habitat for endangered species
- Avoid locations that would block migrating organisms or create a zone of passage that is too narrow



Mixing Zone Location: Human Health

- Restrict mixing zones from areas that would pose significant human health risks
  - Drinking water intakes and sources
  - Shellfish beds
  - Fisheries
  - Recreational areas



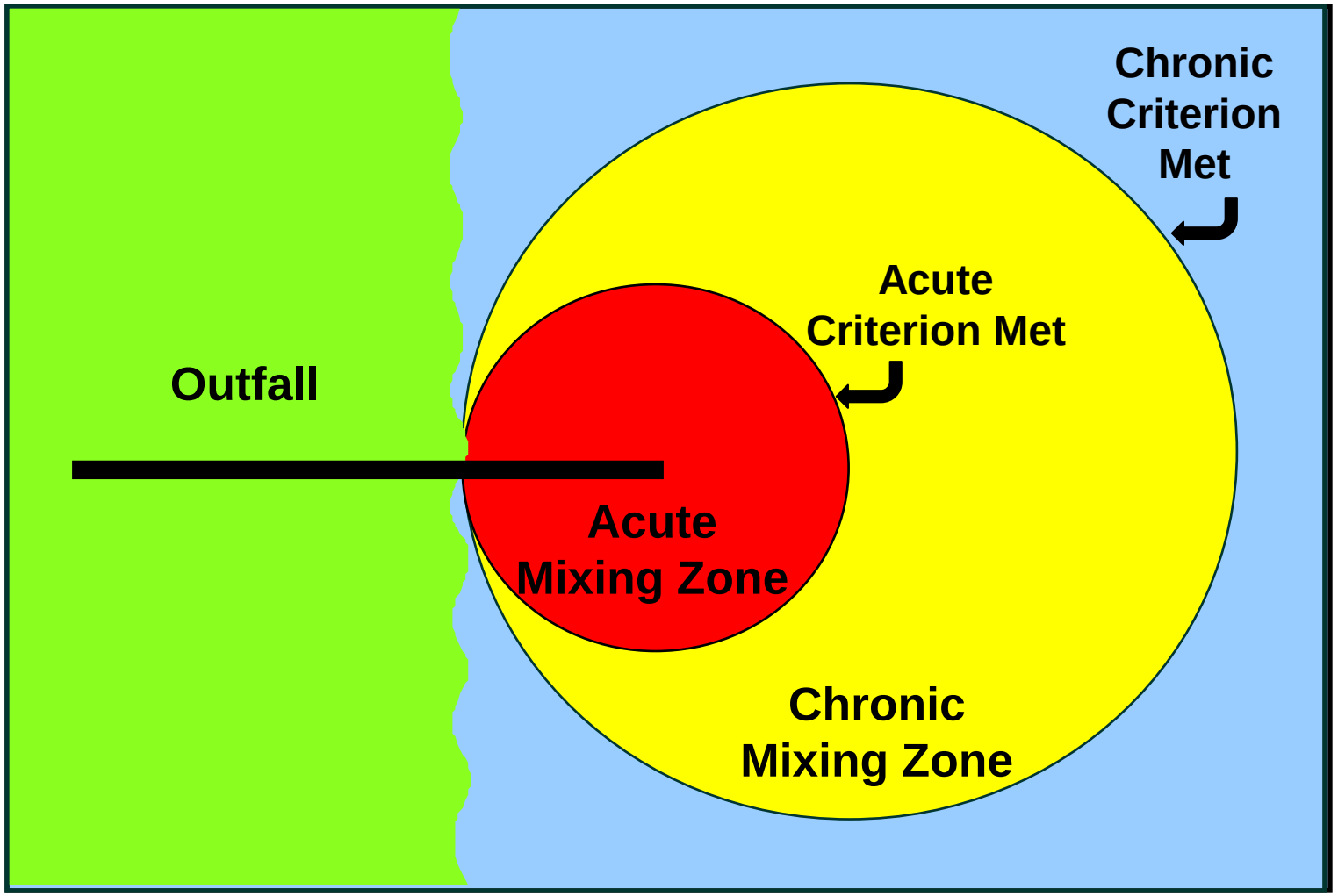
Mixing Zone Size

- Maximum size should be specified in state/tribal mixing zone policy
- Should be no larger than necessary
- Should not hinder movement within the waterbody or into tributaries

Mixing Zones Size Examples

- <1/4 of stream width and 1/4 mile downstream
- <1/2 stream width and longitudinal limit of 5X stream width
- No more than 10% of critical flow
- No more than 5% of the lake surface
- No more than 4:1 dilution for lake discharges
- Less than 10% of a lake's surface area
- Less than 300 feet in any direction

Mixing Zone Size Schematic



Mixing Zone Size and Low Flows

- Stream flow establishes how much dilution is available in the receiving water
- Low flow provides a "worst case scenario"
- EPA low flow recommendations:

Criteria	Hydrologically-based low flow	Biologically-based low flow
Acute aquatic life	1Q10	1B3
Chronic aquatic life	7Q10	4B3
Non-carcinogen human health	30Q5	
Carcinogen human health	Harmonic mean	

Mixing Zone Shape

- Consider the shape of the mixing zone
  - Shore-hugging plumes should be avoided

Wastewater outfall with boundary interaction
Source: I. Wood from www.cormix.info

Mixing Zone Outfall Design

- State should ensure best practicable engineering design

- Factors to consider:
  - Height of outfall
  - Distance to bank
  - Angle of discharge
  - Single or multi-port diffuser

- Modifying outfall design can avoid adverse impacts

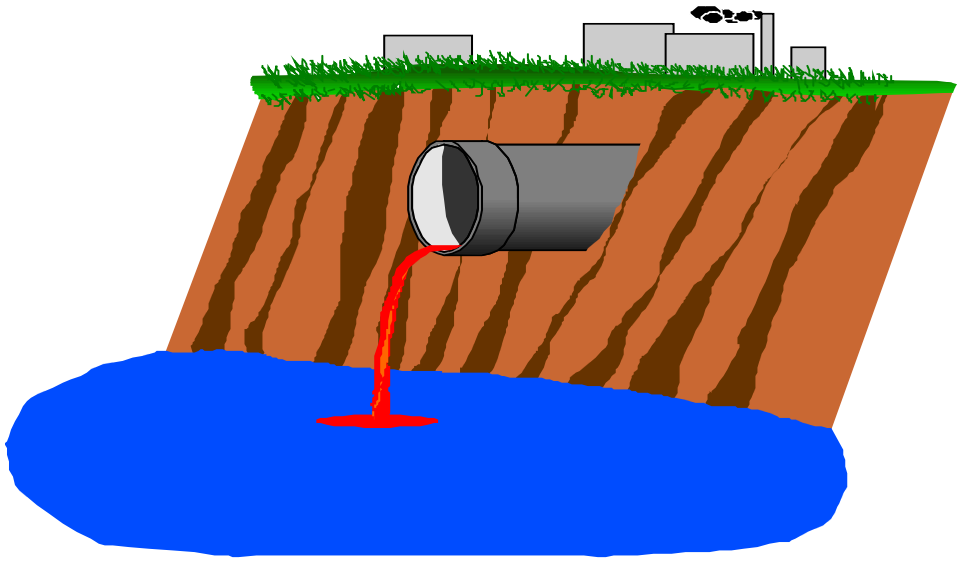
Mixing Zone Water Quality

- Mixing zones should be free from:
  - Concentrations causing acute toxicity
  - Concentrations forming objectionable deposits
  - Floating debris, oil, scum, and other nuisance materials
  - Substances producing objectionable color, odor, taste, or turbidity
  - Substances that result in a dominance of nuisance species

Other Mixing Zone Issues

Is the effluent attractive?

- States and tribes should consider whether a mixing zone may attract aquatic life.
  - For example, temperature can be attractive.



Other Mixing Zone Issues

Are there bioaccumulative chemicals?

- Mixing zones for bioaccumulative pollutants should be carefully considered.
  - Bioaccumulatives are more likely to affect the entire water body
  - Can pose significant human health risks
- May be appropriate to prohibit mixing zones for bioaccumulatives and/or restrict mixing zones where fish or shellfish harvesting takes place

Other Mixing Zone Issues

Is there rapid and complete mixing?

- Rapid and complete (R+C) mixing occurs when the lateral variation of in-stream concentration in the direct vicinity of the outfall is small (e.g., < 5%)
- Can occur when effluent flow > stream flow or when a diffuser is used
- If there is R+C mixing, use of up to 100% of the critical low flow may be acceptable
- If there is not R + C mixing, use of a fraction of the critical low flow may be appropriate

EPA Mixing Zone Guidance

- Water Quality Standards Handbook (1994)
  http://water.epa.gov/scitech/swguidance/standards/handbook/index.cfm
- Technical Support Document for Water Quality-based Toxics Control (1991)
  http://www.epa.gov/npdes/pubs/owm0264.pdf
- Compilation of EPA Mixing Zone Documents (2006)
  http://water.epa.gov/scitech/swguidance/standards/mixingzones/index.cfm

Review Question #1

- What is the primary purpose of a state/tribal mixing zone policy?
  a. Provide an effluent dilution function
  b. Create spatial variations in the effluent plume
  c. Create areas with less desirable water quality
  d. Restrict areas where numeric criteria can be exceeded and reduce the need for excessive wastewater treatment

Review Question #1

- What is the primary purpose of a state/tribal mixing zone policy?
  a. Provide an effluent dilution function
  b. Create spatial variations in the effluent plume
  c. Create areas with less desirable water quality
  d. Restrict areas where numeric criteria can be exceeded and reduce the need for excessive wastewater treatment

- Answer:

  d. The primary purpose of a mixing zone is to restrict areas where numeric criteria can be exceeded and limit the need for excessive wastewater treatment.

Review Question #2

- What is the primary reason for regulating the size of a mixing zone and its percentage of the total waterbody?
  a. To protect shellfish beds
  b. To protect human health
  c. To protect the designated use of the waterbody as a whole
  d. To protect drinking water resources

Review Question #2

- What is the primary reason for regulating the size of a mixing zone and its percentage of the total waterbody?
  a. To protect shellfish beds
  b. To protect human health
  c. To protect the designated use of the waterbody as a whole
  d. To protect drinking water resources

- Answer:

  c. Limiting the size of a mixing zone protects the designated use of the waterbody as a whole.

Review Question #3

- True or false? States and tribes are limited in the number and types of issues that may be addressed in their mixing zone policies.

Review Question #3

- True or false? States and tribes are limited in the number and types of issues that may be addressed in their mixing zone policies.

- Answer:
  - *False. States and tribes are encouraged to address as whatever is necessary to protect designated uses.*

Review Question #4

- True or false? At the zone of initial dilution, both acute and chronic aquatic life criteria can be exceeded in a mixing zone.

Review Question #4

- True or false? At the zone of initial dilution, both acute and chronic aquatic life criteria can be exceeded in a mixing zone.

- Answer:
  - *True. Although the area of a mixing zone where acute criteria may be exceeded is smaller, there still can be an area where both acute and chronic criteria are exceeded.*

Review Question #5

- Which of the following could preclude the establishment of a mixing zone?
  a. Area is used for recreational fishing
  b. Bioaccumulative pollutants in the discharge
  c. Proximity to drinking water intakes and sources
  d. Presence of shellfish beds
  e. All of the above
  f. None of the above

Review Question #5

- Which of the following could preclude the establishment of a mixing zone?
  a. Area is used for recreational fishing
  b. Bioaccumulative pollutants
  c. Proximity to drinking water sources
  d. Presence of shellfish beds
  e. All of the above
  f. None of the above

- Answer:

  e. All of these reasons could cause a state or tribe to preclude the establishment of a mixing zone.

Review Question #6

- True or false? EPA recommends that states and tribes keep mixing zone policies short and simple to increase public understanding and maintain flexibility.

Review Question #6

- True or false? EPA recommends that states and tribes keep mixing zone policies short and simple to increase public understanding and maintain flexibility.

- Answer:
  - *False. EPA encourages specific mixing zone policies to limit ambiguity and foster uniformity in NPDES permit limit development. Policies should be clear but not necessarily short and simple.*

Questions?

Chelsea Morris
Standards and Health Protection Division
Morris.Chelsea@epa.gov
202-566-1113